The history and mystery of the LT/LTB/BI lines optics design

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Thanks to:

B.Mikulec, G.P. Di Giovanni, T.Dobers ←model of the lines

J.Tan, M.Bozzolan, L.Søby ←Identification of optics design problem

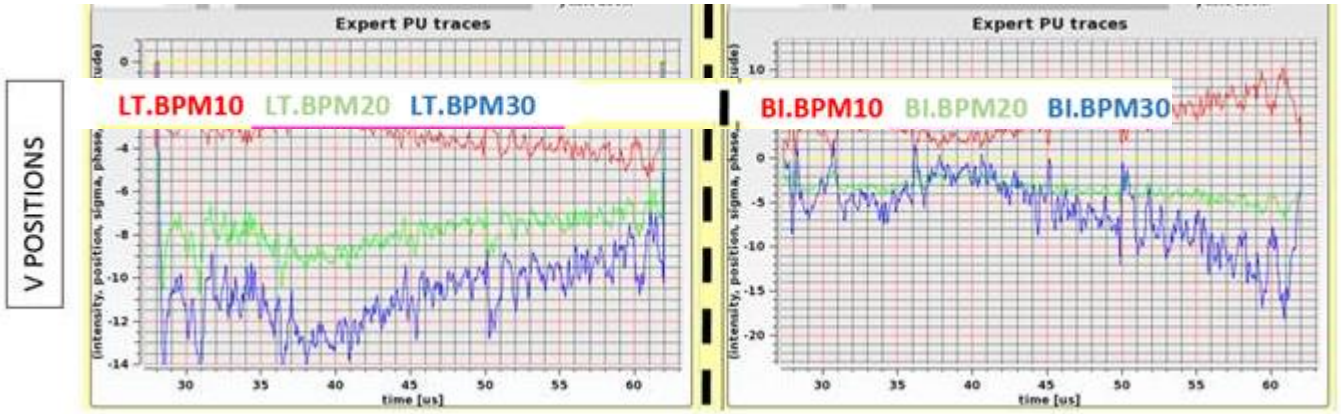
In this talk, the following arguments will be made:

1) We observe position fluctuations (vertically) in the last two pickups in the BI line.
2) These fluctuations comes from the beam and are not in any way related to the electronics, cables or any technical feature.
3) With the present model of the optics, we cannot understand these fluctuations. Neither if they come from a vertical transverse beam distribution nor from real position fluctuation.
4) Therefore, we do not understand the optics at the end of the BI line.
5) It is not possible to guarantee that the beam will fit within the apertures of the proposed upgrade, unless the optics is better understood.

Identification of the optics design problem

Large vertical fluctuations on the last two pickups on the BI line

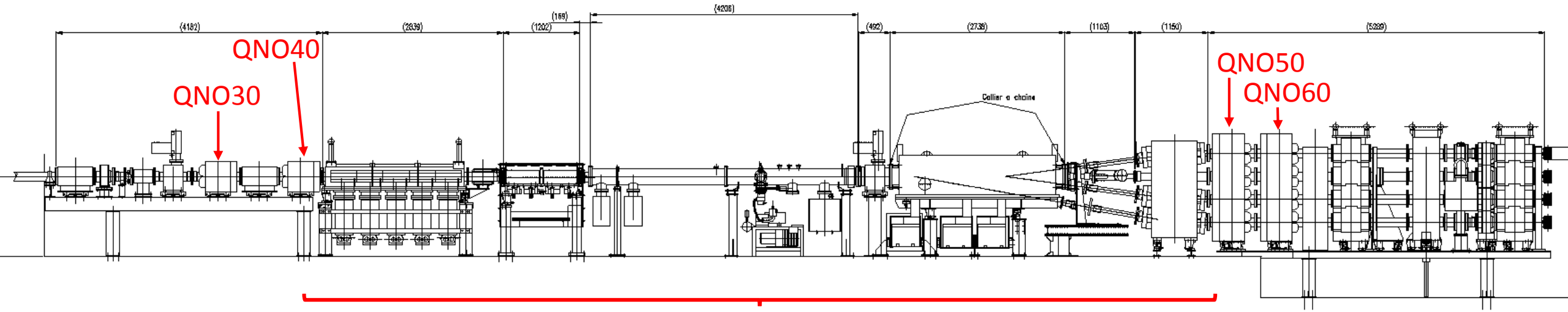
The fluctuations from all the pickups are correlated



- Some measurements indicate that the fluctuations are proportional to the square root of the beta functions. However, some measurements disagree.
- The design of all the pickups in the LT, LTB and BI lines is identical.
- The pickup design is symmetrical, i.e. horizontal plane and vertical plane depends only on the rotation of the pickup
- It has been verified that the electronics and the cabling work perfectly!
- The fluctuations are **not** transported down the line according to the optics TRANSPORT MATRIX!!!
- YASP is currently not used to correct the injection trajectories with the last two BPMs. The two correctors BIx.DHZ/DVT50 and BIx.DHZ/DVT70 (BIx.BPM40 and BIx.BPM50 are in between) are tuned separately to define the PSB injection position and angle.

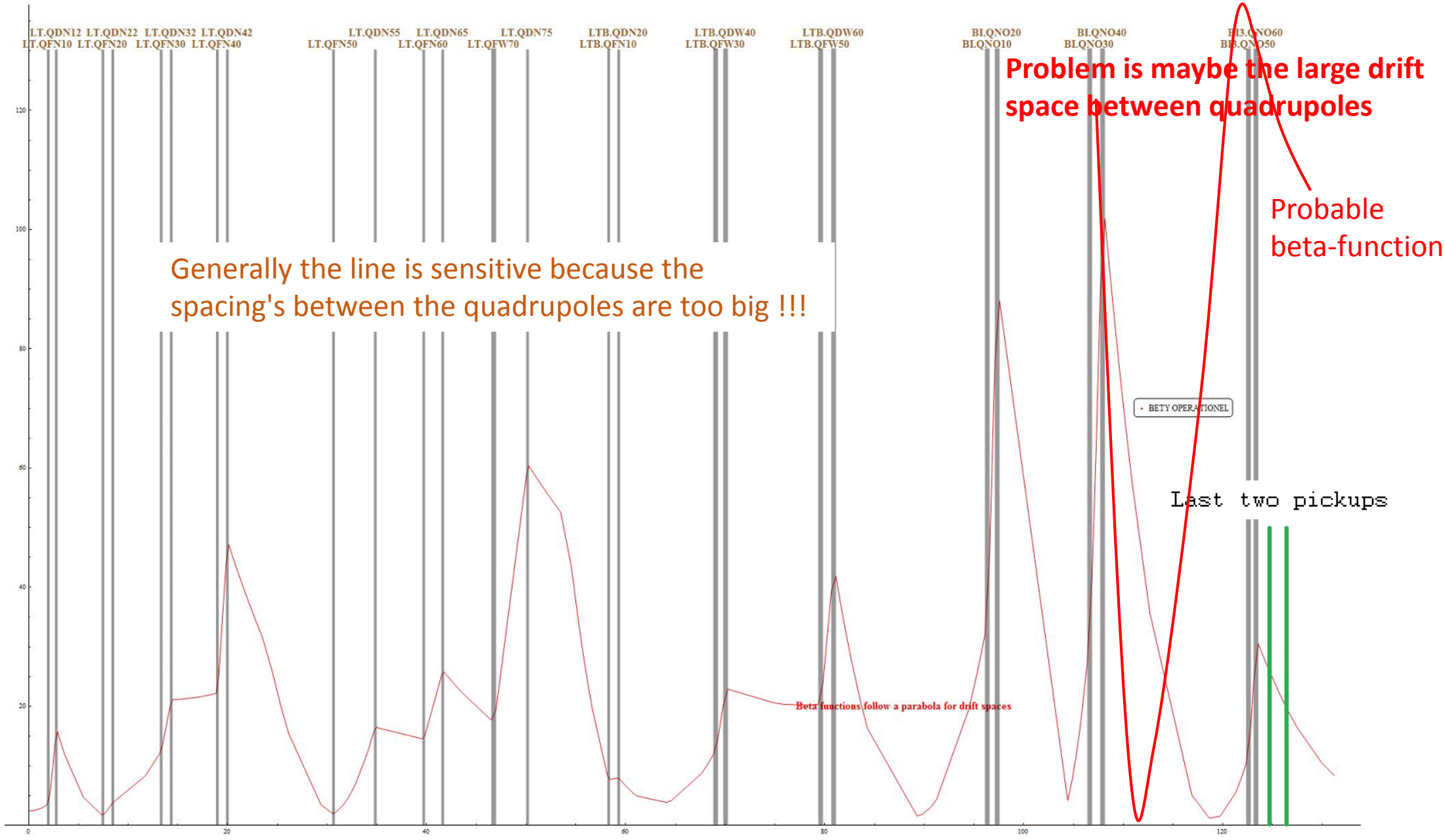
One hypothesis is that the fluctuations are caused by an asymmetric transverse distributions that vary from beam to beam and are amplified by the beta functions. These asymmetric beam distributions propagate down the lines in a 6D fashion. The hypothesis also assumes that for the last two pickups the vertical beta functions are enormous!!!
However MADX says the beta functions at the last two pickups are small, which indicates we do not understand the optics at the end of the BI line.

Identification of the optics design problem
Why could the beta functions be enormous at the end of the BI line?
Assumption #1: The distance between quadrupoles is too large



Problem is maybe the large drift space between quadrupoles

Identification of the optics design problem
Assumption #1: The distance between quadrupoles is too large



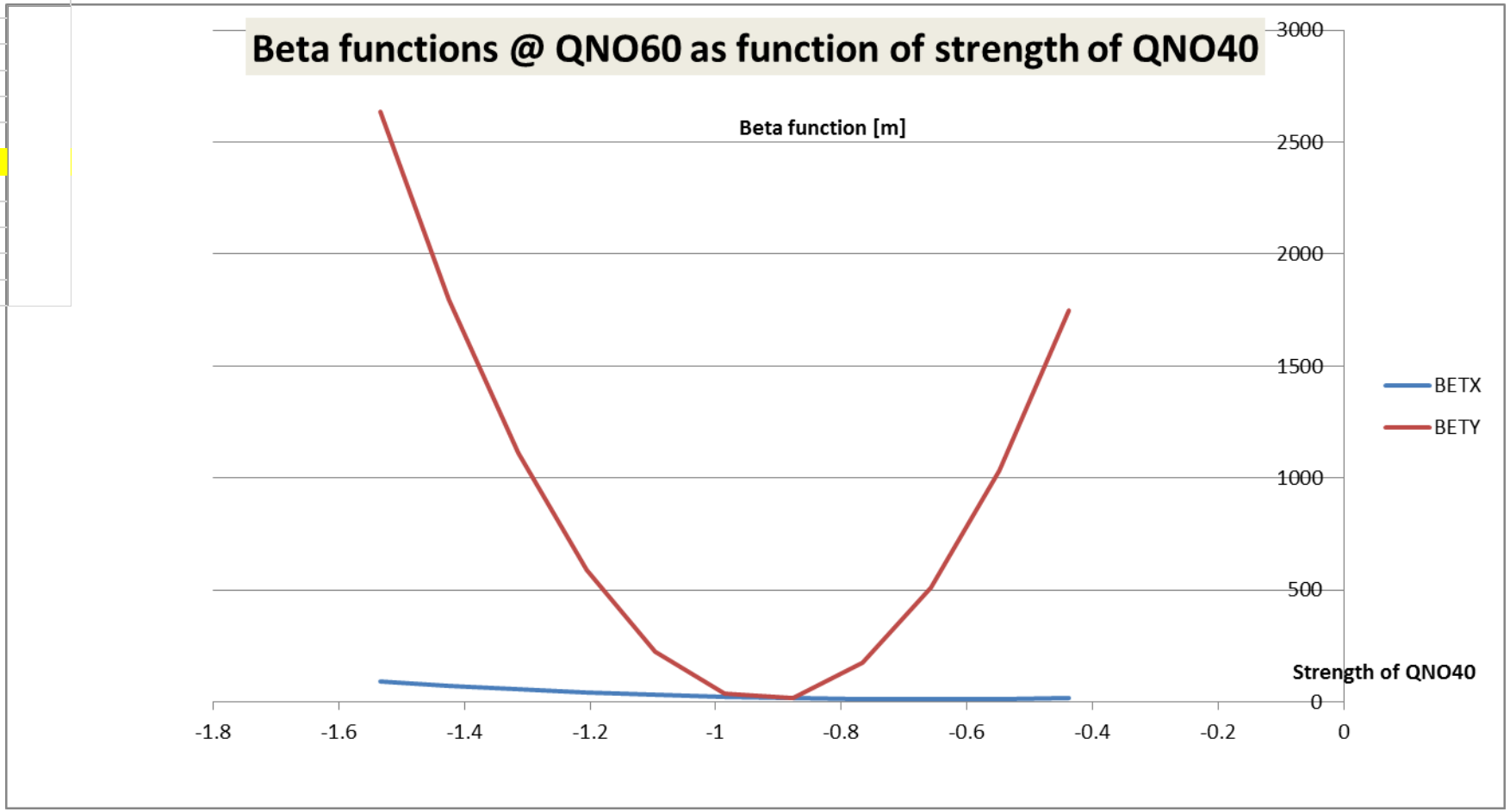
Identification of the optics design problem
Assumption #1: The distance between quadrupoles is too large

Beta-function @ QNO60 as function of strength of QNO40

strength=	-1.534	BETX=	92.00618	BETY=	2634.489
strength=	-1.425	BETX=	73.48934	BETY=	1797.777
strength=	-1.315	BETX=	57.45837	BETY=	1110.505
strength=	-1.206	BETX=	44.14751	BETY=	588.9649
strength=	-1.096	BETX=	33.25532	BETY=	227.4802
strength=	-0.986	BETX=	24.85873	BETY=	35.5474
strength=	-0.877	BETX=	18.94483	BETY=	16.5604
strength=	-0.767	BETX=	15.34997	BETY=	174.211
strength=	-0.658	BETX=	14.08573	BETY=	509.6736
strength=	-0.548	BETX=	15.07511	BETY=	1033.244
strength=	-0.438	BETX=	18.28673	BETY=	1746.901

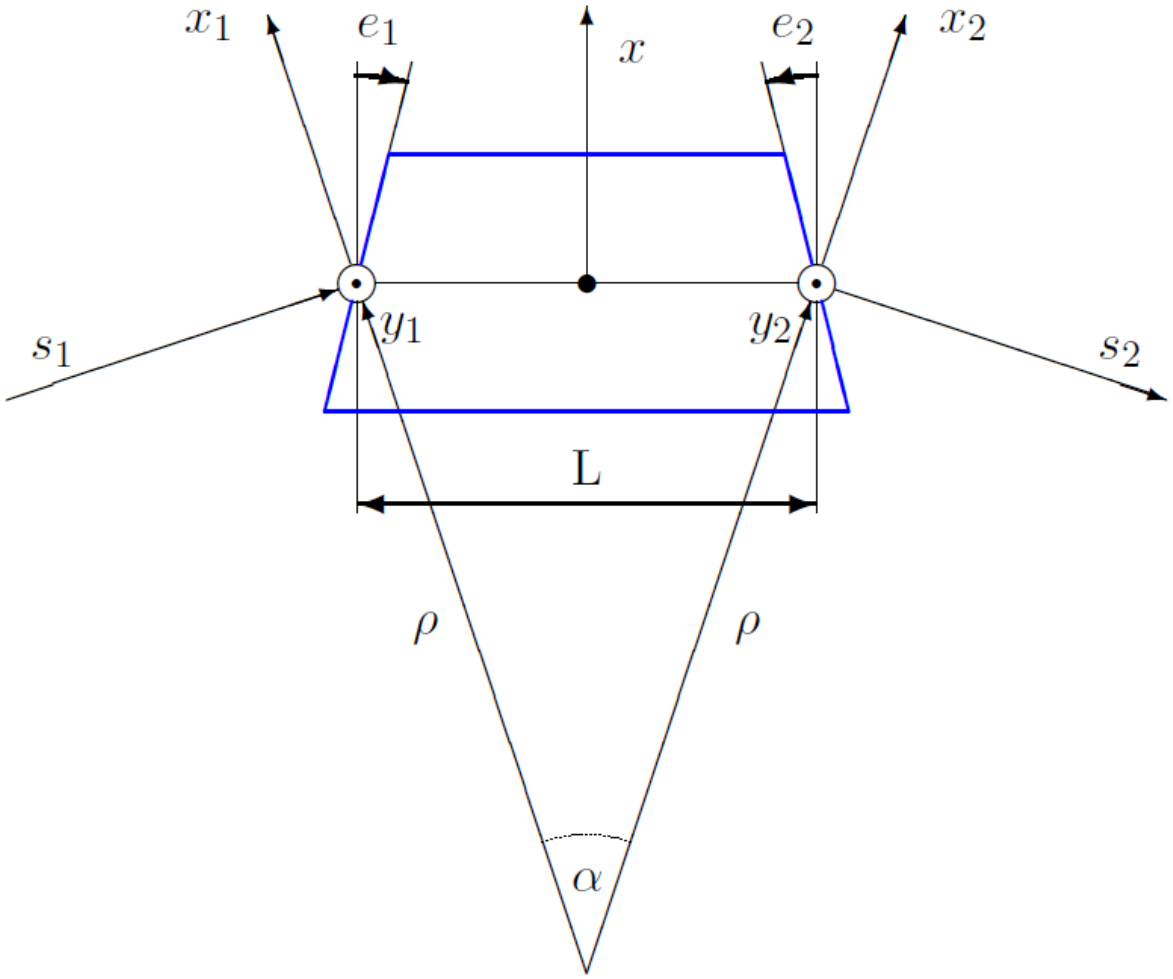
How well do we know the conversion from current to strength of the quadrupoles?

Sensitivity analysis



Identification of the optics design problem

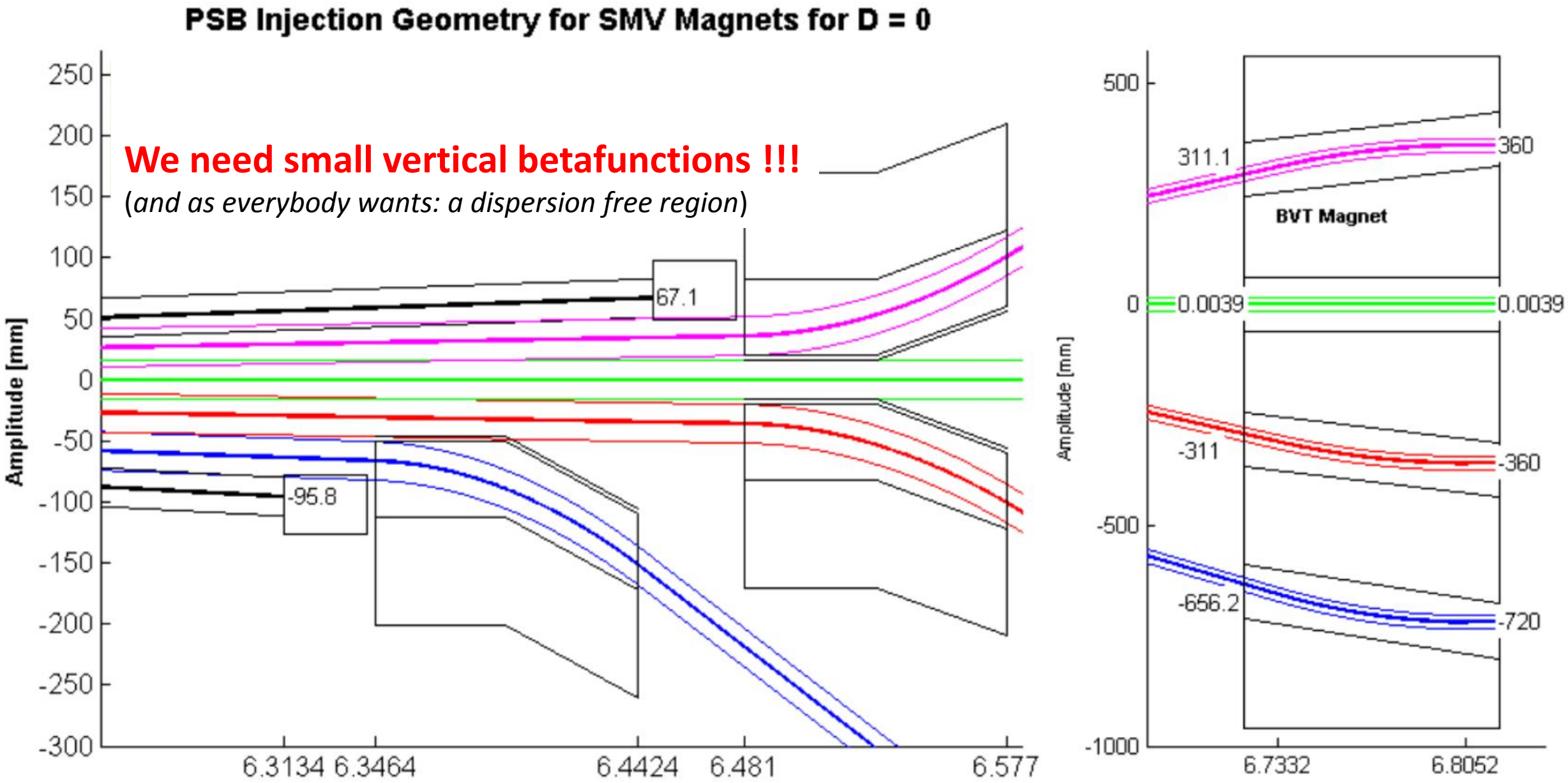
Assumption #2: The modelling of the distributer magnets/SMV10/BVT10 is not accurate



If the pole face angles of the DIST/SMV10/BVT10 are not accurate, then the effect will be felt essentially only in the vertical plane.

Vertical aperture restriction at the SMV10

(*we need to understand the optics correctly, in order to verify that the beam size is adapted to the aperture restriction*)

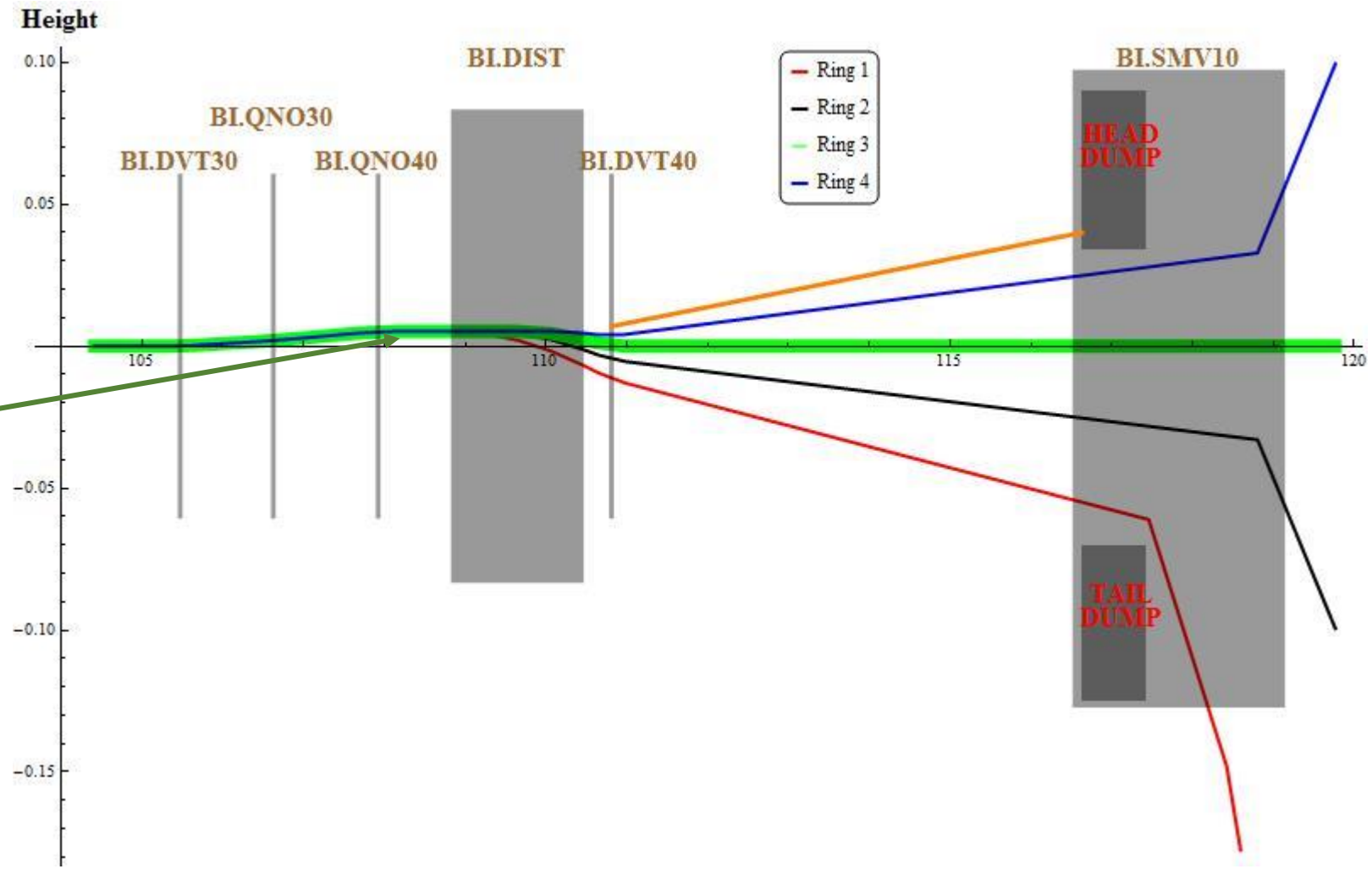


https://edms.cern.ch/edmsui/file/1170734/2.0/PSB-MSMIB-EP-0001-20-00.pdf

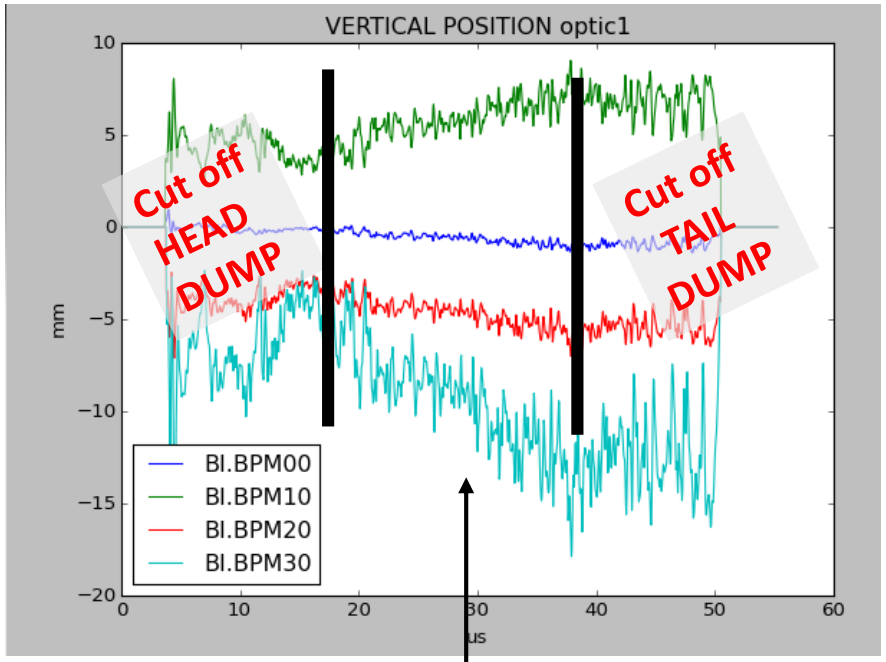
Safety issue: If the distributer is malfunctioning, the beam must be dumped

If the distributer does not give a kick, then the beam follows the orange curve and is dumped on the HEAD DUMP

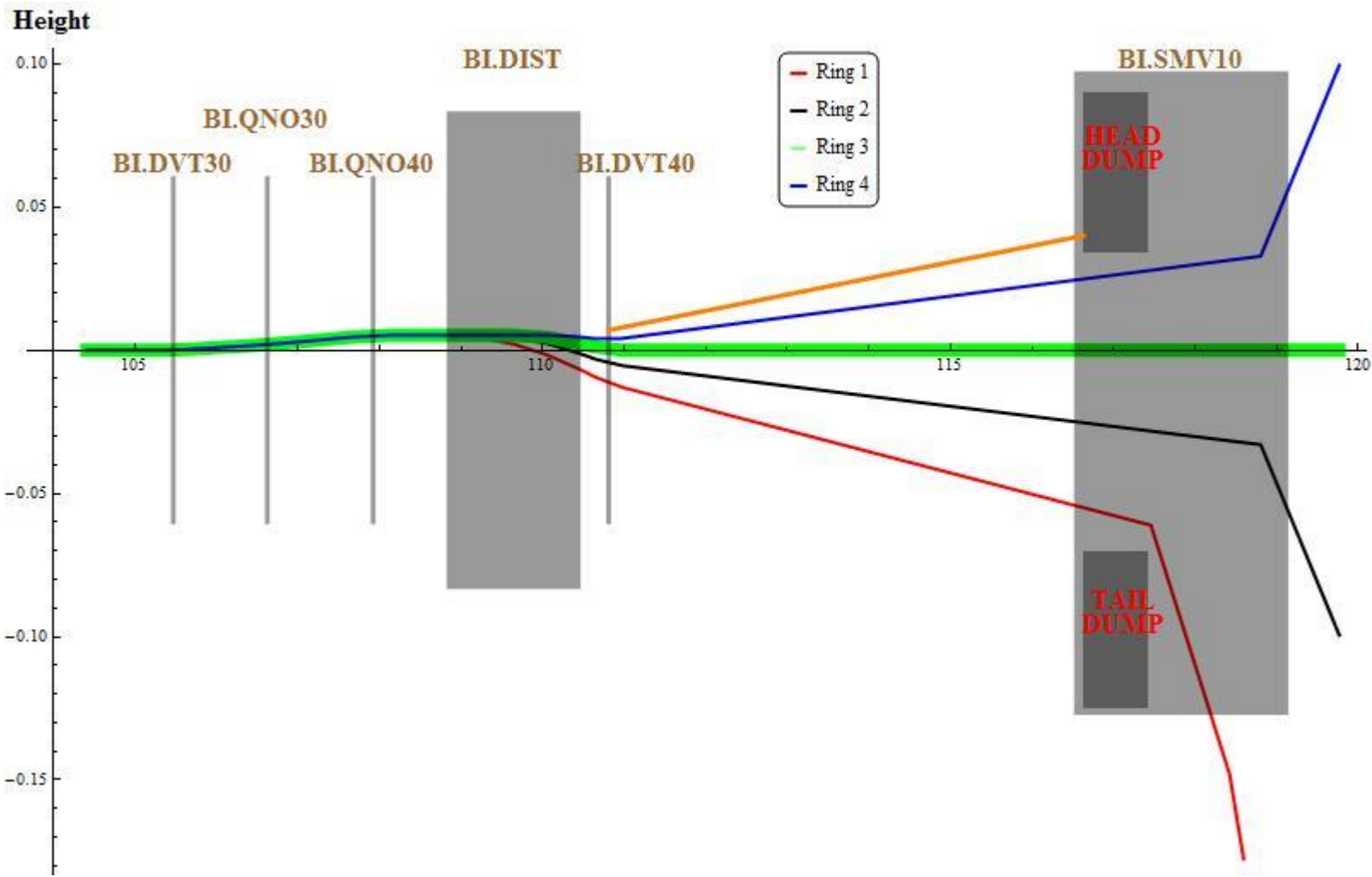
The small offset (5.2 mm in the old design of the BI line) is necessary because the distributor must actively bring the beam in the right position.



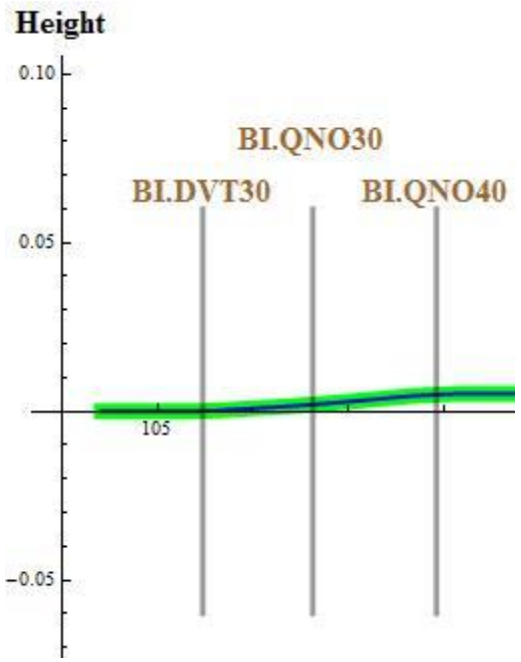
Only the middle part of the pulse from LINAC2 is used. The head and tail of the pulse are dumped



Only this part is sent to the BOOSTER



Non optimal optics design for QNO30 and QNO40, when creating 5.2 mm offset



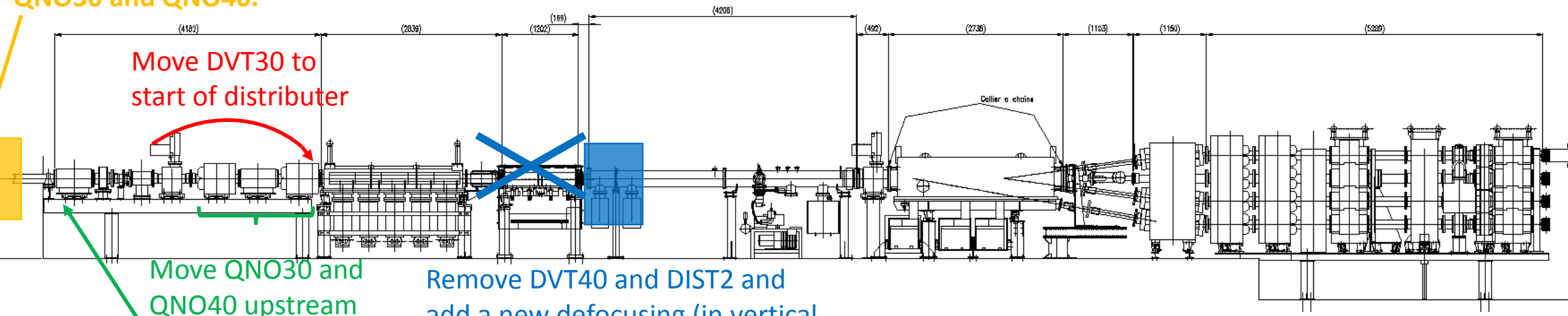
Since QNO30 and QNO40 are used to set the offset before the distributer, their strengths are basically locked. They are never changed by the operators!

This means that basically they cannot be used to regulate the beta functions around the SMV10. There are no degrees of freedom.

NB! *The QNO30 is a type QF quadrupole, it is de-focusing in the vertical plane. QNO40 is type QD, i.e. focusing in the vertical plane*

Possible changes in the optics design for the BI line. (*does not include beam instrumentation, only optics elements*)

Add new defocusing (in vertical plane) quadrupole somewhere between QNO20 and QNO30. Same type as QNO30 and QNO40.



Move DVT30 to start of distributer

Move QNO30 and QNO40 upstream to start of table. Increase distance between them. Change their polarity.

Remove DVT40 and DIST2 and add a new defocusing (in vertical plane) quadrupole in the place of the vacuum pump. The quadrupole is vertically displaced, so it works as a dipole; essentially replacing DVT40. Possibly move DIST downstream.

Possible changes in the optics design for the BI line. (*does not include beam instrumentation, only optics elements*)

The reasons behind the changes are the following:

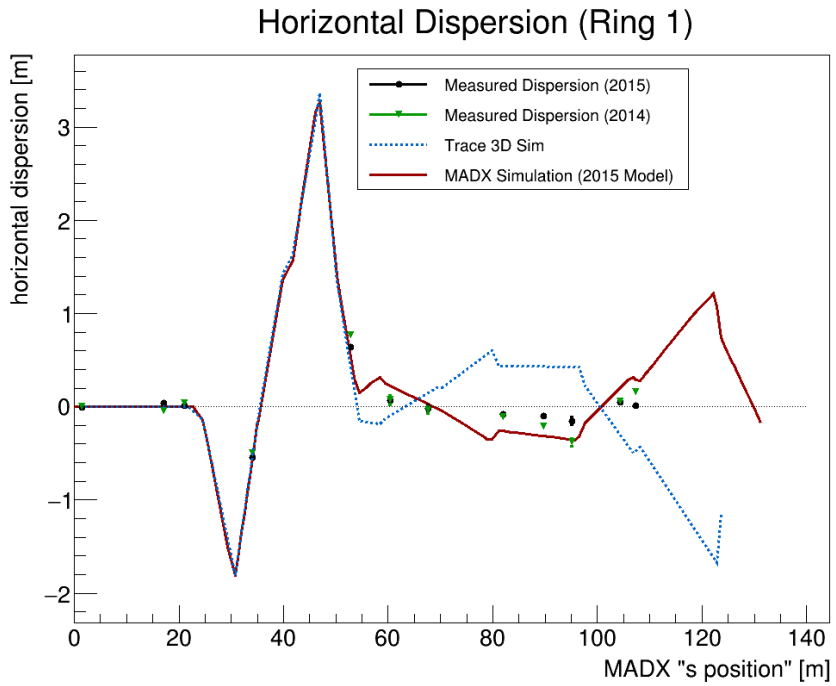
1) There is no need for a straight offset (i.e. 5.2 mm) of the beam inside the distributer. An angle is fine; the DIST will bend the beam down and the DVT40 (or an offset quadrupole) will straighten the beam to the level of ring 3. Placing the DVT30 right in front of the distributer will make that angle. It frees the QNO30 and QNO40 to control the beta-functions. **This change should most probably be done in any case**.

2) The quadrupole that is added between QNO40 and QNO50, is to control the beta functions better and also to replace the DVT40.

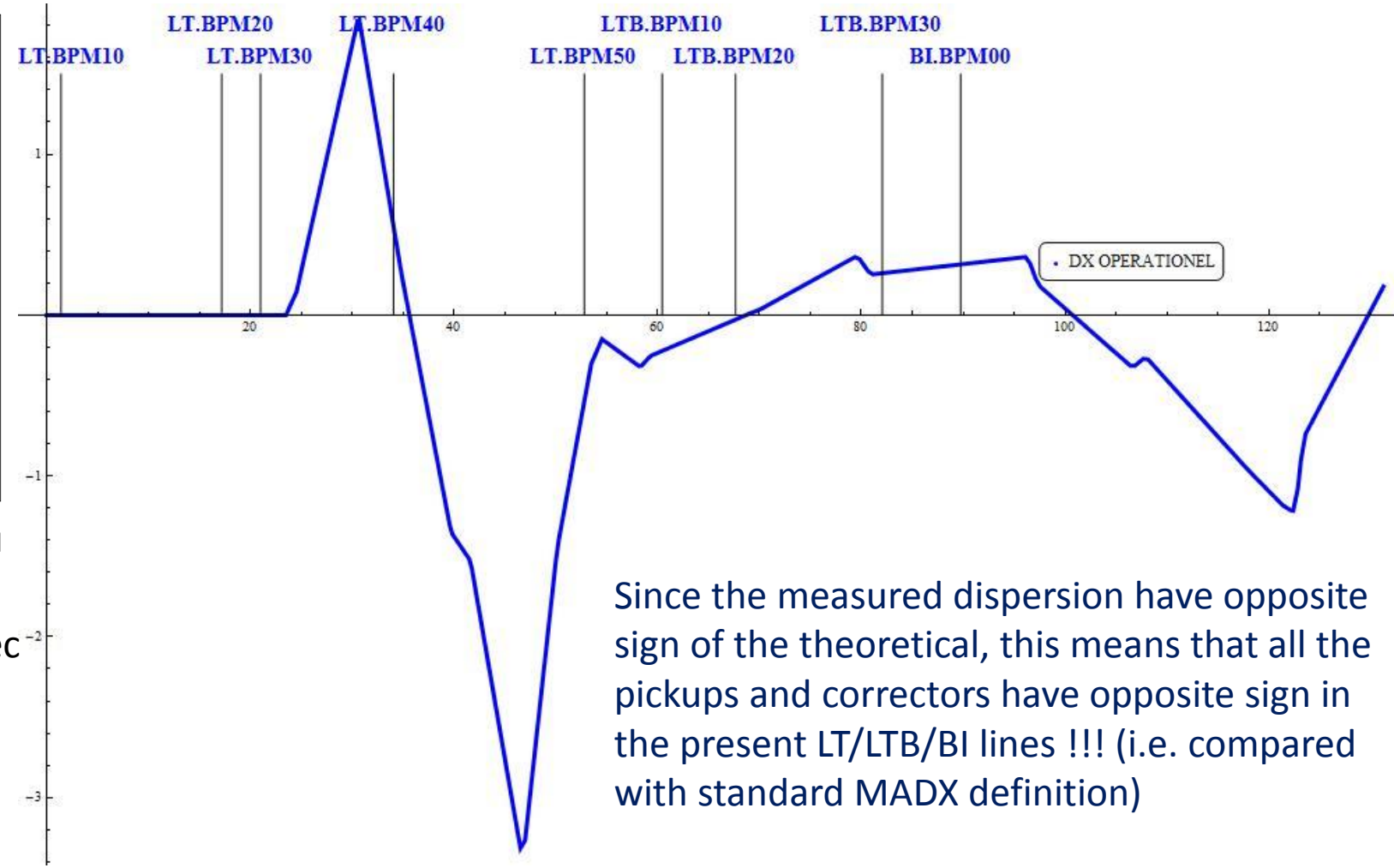
3) The quadrupole that is added between QNO20 and QNO30, is to control the beta functions better and to ensure the sequence of QD, QF,QD,QF etc.

These changes needs to be checked in detail.

Dispersion has opposite sign for the present LT/LTB/BI lines. The sign of the dispersion in the new design should be verified



The real horizontal dispersion, with correct sign



MSWG meeting - PSB YASP.

3 July 2015. G.P. Di Giovanni, O.Berrig, B.Mikulec

The MADX simulation (2015 Model) shown here, is with opposite sign !!!

Since the measured dispersion have opposite sign of the theoretical, this means that all the pickups and correctors have opposite sign in the present LT/LTB/BI lines !!! (i.e. compared with standard MADX definition)

At the end of the BI line #1 DISP1= 0.18 and DISP2=0.12, while they should have been DISP1-1.5 and DISP2=0.

All four BI lines ends with different dispersions. The BOOSTER and the present BI line design have dispersion mismatch (theoretically).

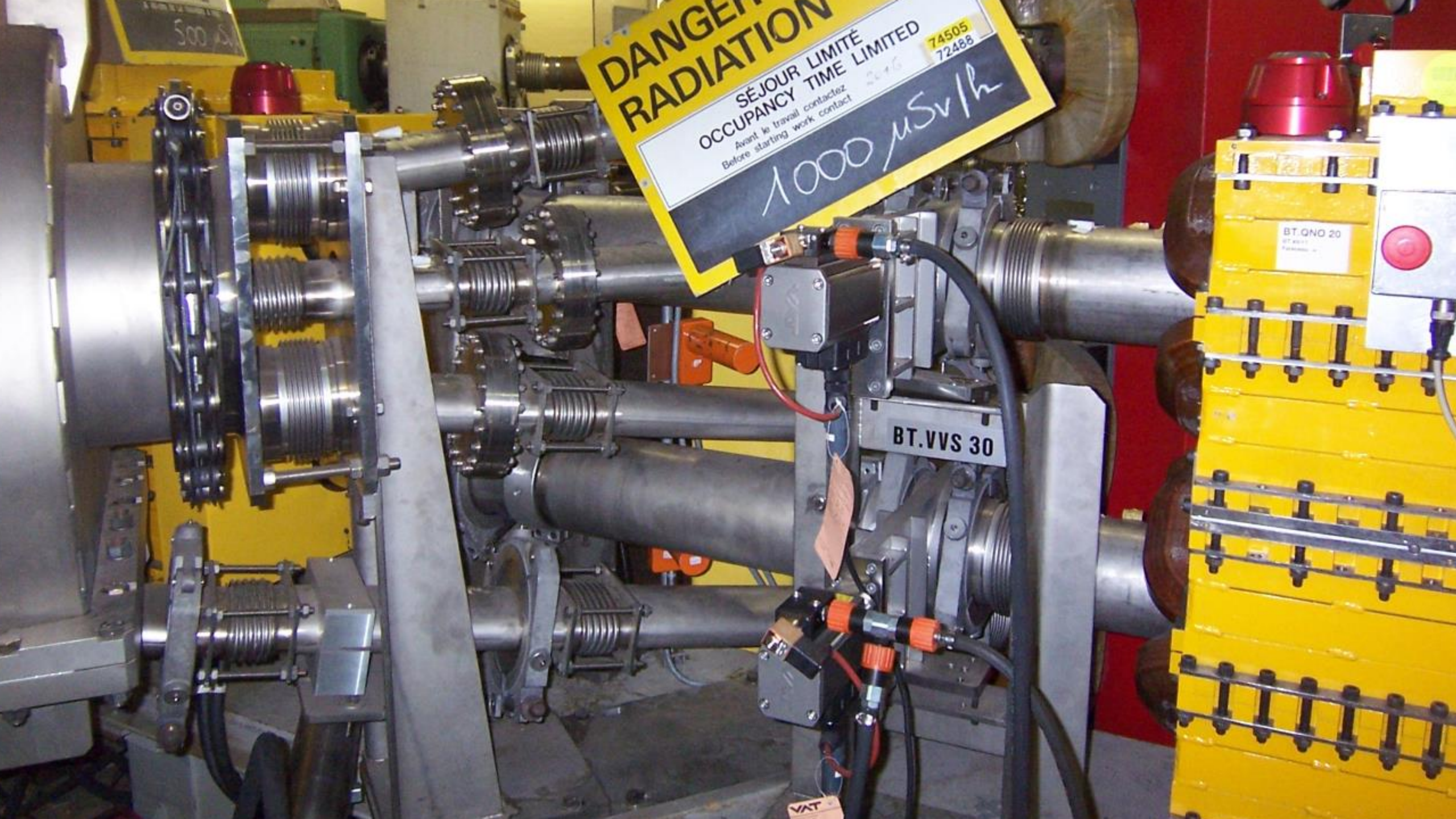
The sign of the dispersion of these lines should be defined in the same way as other lines in CERN.

Recommendations

- Make MD's with the extended kick/response method (i.e. including changing the strengths of the quadrupoles); in order to understand the optics of the last part of the BI line (BOOSTER injection). Needs program development and is hampered by the oscillations of the vertical positions of the last two pickups.
  This should tell us if the model of the DIST/SMV10/BVT10 is wrong or the problem is in the large distance between the pickups.
- Further study the measurements done by the BI group, and try to understand what features of the beam could create these effects. Possibly new MDs.
- Verify apertures of the upgrade of the BI line. Do we have enough flexibility to reduce the beta functions where there are aperture limitations? Do we have blown-up beta functions that will create new aperture restrictions?
- Verify survey of the upgrade of the BI line; especially the 5.2 mm offset(or rather the new offset for the upgrade) and also the levels of the 4 BOOSTER rings.
- Make a meeting with all interested parties, to talk about changes to the design of the LT/LTB/BI lines.
- Take action to use the same sign convention in the LT/LTB/BI lines as everywhere else in CERN and compatible with MADX.
- Make a dedicated program (replacing YASP) to control the injection into the BOOSTER. This program should be able to change the strengths of the DIST, quadrupoles, SMV10, BVT10 and correctors.

Conclusion

- With the uncertainty in the understanding of the optics at the end of the BI line, it cannot be guaranteed that the apertures of the elements are big enough.


DANGER
RADIATION
SÉJOUR LIMITÉ
OCCUPANCY TIME LIMITED
Avant le travail contactez
Before starting work contact
74505
72488
1000 µSv/h
BT.VVS 30
BT.QNO 20


DANGER
RADIATION
SÉJOUR LIMITÉ
OCCUPANCY TIME LIMITED
ATTENTION
HAUTE TENSION
HIGH DANGER


BT.QNO 40
BT #9
Faisceau →
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